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THE IMPACTS OF WIND FARMS ON ANIMAL SPECIES

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Wind farms are constructed in various areas without considering the protected animal species that are present there. In problem areas, there are some mitigation measures taken. In 55% of the studies, bird mortality rates ranges from 0.0 to 2.0 fatalities/turbine/year. 79.4% of the evaluated mortality rates for raptors range from 0.0 to 0.1 fatalities/ turbine/year. The highest number of wind turbine fatalities has been recorded with a raptor Buteo jamaicensis, followed by seagull Larus argentatus, passerine Eremophila alpestris and domestic pigeon Columbia livia. The only species that has been recorded as a wind turbine fatality and is a part of the IUCN Red list of Threatened Species is red kite (Milvus milvus). The European wind power studies pay more attention to the disturbance of particular species. The species that are most commonly considered threatened are the raptors (common buzzard, common kestrel and red kite), grassland birds (common quail, corn crake, lapwing, ringed plover), migrating birds (migrant goose, crane, lapwing, golden plover) and waterbirds (geese species). Bat annual mortality rates range from 0.0 to 47.5 fatalities/turbine/year at different wind farms. The highest mortality rate has been reported for bat species Laisurus cinereus, Lasiurus borealis, Lasionycteris noctivagans and Nyctalus noctula.

Key words: mortality, disturbance effect, bats, birds, wind farms, wind turbines

INTRODUCTION

Greenhouse gases, global warming and air pollution legislation are the environmental issues that increased the demand for renewable sources of energy. Wind energy is considered environmentally friendly in comparison to the conventional energy sources. This caused a rapid expansion of wind farms in Europe and worldwide. However, there are some disadvantages that arise from wind farm operation and they have been discussed in several studies.

The conflict with protection of bird habitats is an important issue in spatial planning of wind farms. It has been estimated that a lot of birds are killed annually due to collisions with human-made obstacles - vehicles, aircrafts, buildings, windows, power lines and communication towers. Klem (1991) reports that vehicles cause 19.7 % of bird mortality caused by humans. In the USA, this amounts to approximately 300 million birds annually (Erickson *et al.,* 2001). Most birds are undoubtedly killed by highway traffic. However, planes and trains also cause a significant number of victims (Spencer, 1965). The Federal Aviation Administration in the USA reported over 3500 bird strikes by planes in 1998. It is estimated that civil aircrafts strike over 25000 birds per year. However, there are no available estimations for trains (Erickson *et al.,* 2001). Klem (1990) estimates that the mortality related to window collision ranges between 97.6 to 976 million annually. The estimation ranged from 1 to 10 fatalities per structure per year in the USA. In Holland, Koops (1993) estimated 750000–1000000 bird fatalities annually due to collisions with high-voltage lines. There are only 4600 km of high-voltage lines in Holland, while there are 800000 km in the USA, which means 130–174 million bird fatalities. Banks (1979) and Evans (Manville, 2000; Erickson *et al.,* 2001) estimated that the annual number of victims varies from 4 to 5 million. Certainly, there are no wind turbine impact studies that would reveal the mortality rate higher or even close to the mortality rate caused by TV towers, chimneys and other tall structures.

There are three significant impacts on the populations of birds and bats:

– habitat destruction and loss,
– collisions,
– disturbance.

Collisions present the greatest threat to bird populations.

Bird fatalities occur in various groups, from raptors and sparrows to water and shore birds. The relative density of bird species does not consider the relative frequency of fatalities per species (Thelander and Rugge, 2000).

There are numerous factors that can contribute to increased mortality. In the postconstruction phase, some species can become more sensitive to collisions because of the increased amount of prey near the turbines. The areas with disturbance become more appropriate for animals sheltering in dens, and most of those animals are an attractive prey for birds. If a turbine is situated on a pasture, the cattle often gather around it to seek shadow. Cattle excrements attract insects and insects attract birds. The mortality is further influenced by fog, clouds, rain and darkness. 51 out of 55 bird fatalities (97 %) in Buffalo Ridge wind plant occurred in bad weather conditions (Johnson *et al.,* 2002). Aircraft lights, set on top of turbines that are higher than 60 m, can also cause collisions. In a surveyed wind plant in Nine Canyon (USA), the mortality rate was higher at illuminated turbines than at those without lights (Erickson *et al.,* 2003). It seems that birds are most sensitive to red lights. A pulsating red light on foggy or low cloud-ceiling nights can disturb the navigation of birds (Johnson *et al.,* 2002). Seasonal migration is one of the main bird activities and it can lead them in the vicinity of wind turbines. Most birds migrate at night when they are less able to notice tall structures on their way.

Based on studies and monitoring results in the postconstruction phase we listed the impacts on particular species (protected or unprotected) with analysis of the following parameters: number of bird fatalities by species, number of bat fatalities by species, bird mortality rate per turbine per year and bat mortality rate per turbine per year. We tried to answer one of the basic questions: How acceptable is the construction of wind turbines in a particular area from the aspect of their impact on living organisms?

MATERIAL AND METHODS

Is it possible to foresee the impacts of future wind plants based on the experiences from the old ones? To achieve this, we need to choose the appropriate methods for a synthesis of the information from previously made studies. The demand for long and expensive studies on each new location could be diminished by collecting the existing findings that would be useful when researching new areas. The existing results of extensive studies should be compared to the small-scale, specific studies of particular areas and this is how the impact should be evaluated and predicted.

Our research was limited to on-shore wind plants. The analysis of environmental impact assessments was based on a collection of documents from various countries that already use the wind energy as an alternative energy source. The documents were collected with the help of energy distribution companies, local environmental institutions and web pages. During data collection, we faced some difficulties, mainly because the requested data was considered confidential by the investors. Furthermore, the environmental impact assessments are not publicly available documents in most countries.

In the postconstruction phase, the actual impacts on animal species and their vulnerability on particular locations are defined, based on monitoring and research. The analyses of environmental impact assessments and monitoring results in the postconstruction phase present an independent issue that leads to empirical and theoretical conclusions, which can change or improve the existing practice of locating wind farms. Using the SWOT analysis we presented strengths, weaknesses, opportunities and threats of wind farms in relation to the environment. Finally, we added some recommendations for the future.

RESULTS AND DISCUSSION

Most world studies base their conclusions on monitoring results. Some use the results of preconstruction monitoring and others use the results of post-construction monitoring including data on mortality. There are also a few studies that include both. Since our study demanded various types of data, we included most monitoring results we received although some studies are incomplete or include various types of data. In total, we used 70 monitoring studies and 35 environmental impact reports from different world countries.

Wind farms and protected animal species

According to analysis of environmental impact reports, wind turbines are constructed in various areas irrespectively of protected or endangered species that live there, except for the areas that are defined as protected. We did not find a single case of a project refusal based on the presence of endangered mammals, reptiles or amphibians. Birds are an exception here. The project proposal is refused if the area is specially protected as a natural park or a protected area under Natura 2000. There are certain accepted projects that are located adjacent to the protected areas or even interfere with a smaller part of it (Obersiebenbrun, Potzneusiedl in Austria). All reports provide a detailed list of bird species in the area intended for wind turbine constructions. The list is made according to monitoring that usually takes one year.

Most reports also include the information on present or potentially present mammals, reptiles, amphibians and nonvertebrates. The emphasis is certainly on bird and bat species, owing to the significant possibility of direct negative impact – a collision with the turbine. Evidently, only a minority of reports manages to predict a potential collision rate for birds or particular bird species. The rate predicted in the reports uses calculations on the basis of mortality rates in the nearby or similar (relief features, turbine type) wind farms. The calculations are further based on the bird population in the area intended for wind farms.

Similar calculations are scarce in case of bat species, since data on bat mortality and density of bat population in the particular area is usually not available. Because of the regular ornithological monitorings, the data on mortality rates is available for planned wind farms in the USA and Australia. According to our analysis, there are hardly any estimations available for Europe. In problem areas, there are some mitigation measures taken (obligatory location of wind turbines some 100 metres away from the nests of threatened species, taboo zones). Wind turbines are usually constructed in areas with smaller bird and bat activity and rarely on the main migration routes (owing to the negative experiences from some of the existing wind farms, e.g. Tarifa, Spain) and important feeding areas.

Out of 45 surveyed monitorings with defined research duration to last one year. The average duration of monitoring is 1.6 years. Wind farms vary according to the number of turbines; from 1 up to 5400 turbines per farm. The largest wind farms are located in the west of the USA. When calculating mortality rate, most studies include the parameters of effective searching and carcass removal. Some studies focus only on the number of victims found and do not provide the mortality rate estimation for a monitored wind farm.

The mortality rate for raptors is recorded separately in some studies. 51 studies recorded bird mortality rate and 34 out of them recorded collision rate for raptors. The mortality rate for all bird species varies from 0.0 (Le Nordais/Canada, Bryn Tytli/Great Britain, Haverigg/Cumbria, Garett/USA, Green Mountain/USA, Iowa/USA, Somerset County/USA, St. Mary/USA) to 64.26 fatalities/turbine/year in El Perdon, Spain. Most mortality rates range from 0.0 to 2.0 fatalities/turbine/year (in 55% of studies). In 11% of studies, the mortality rate is extremely high, namely 25.75, 35.05 and 64 fatalities/turbine/year for Spanish turbines. The differences among the rates originate from different research and calculation methods. Owing to the methodological differences, there are also significant differences between European and American wind farms. In case of American wind farms, several studies are made for a single wind farm. Therefore, the calculated rates are more reliable, which is not the case for European ones. Due to the differences, the estimated rates could be over or underestimated. Almont Pass (USA) and Tarifa (Spain) are frequently mentioned as problematic. The mortality there is under 1 fatalitie/turbine/year for all species and under 0.4 for raptors, thus the other high mortality rates seem unreliable and would certainly be mentioned in the reports.

The estimated mortality rate for raptors ranges from 0.0 to 8.33 fatalities/turbine/year. In 34 studies, 79.4% of the estimated rates range from 0.0 to 0.1 fatalities/turbine/year. 14.7% of the estimated rates range from 0.1 to 0.5 fatalities/turbine/year. There is one case of an extremely high estimation – 8.33 in Salajones (Spain). The lowest numbers of fatalities is recorded in agricultural areas, while the highest on the mountain ridges of Spain and in the wetlands of Belgium.

Bird species that prevail among the fatalities vary according to the particular area. Raptors prevail in the USA and Spain, while there are many different species that prevail in central and northern Europe (seagulls, buzzards, kestrels and others).

Monitorings and mortality according to particular bird species

Table 1. The most frequent species mentioned as wind turbine fatalities in the studies (above 10 reported fatalities)

Bird species	Latin name	Number of fatalities	Number of studies
Sky Lark	*Alauda arvensis*	15	4
Chukar	*Alectoris chukar*	12	3
Mallard	*Anas platyrhynchos*	37	10
Swift	*Apus apus*	15	4
Golden Eagle	*Aquila chrysaetos*	33	4
Burrowing Owl	*Athene cunicularia*	28	2
Great Horned Owl	*Bubo virginianus*	22	4
Buzzard	*Buteo buteo*	27	2
Red-tailed Hawk	*Buteo jamaicensis*	221	7
Wood Pigeon	*Columba palumbus*	12	5
Rock Pigeon	*Columbia livia*	134	8
Common Raven	*Corvus corax*	29	5
House Martin	*Delichon urbica*	10	4
Horned Lark	*Eremophila alpestris*	156	7
American Kestrel	*Falco sparverius*	82	7
Kestrel	*Falco tinnunculus*	29	4
American Coot	*Fulica americana*	10	4
Griffon Vulture	*Gyps fulvus*	133	1
White-tailed Eagle	*Haliaeetus albicilla*	13	1

Cont. Table 1.

Bird species	Latin name	Number of fatalities	Number of studies
Herring Gull	*Larus argentatus*	192	6
Common Gull	*Larus canus*	14	5
Lesser Black-backed Gull	*Larus fuscus*	45	2
Black-headed Gull	*Larus ridibundus*	87	3
Red Kite	*Milvus milvus*	44	3
Ring-necked Phesant	*Phasianus colchius*	32	6
Patridge	*Perdix perdix*	14	5
Ring-necked Phesant	*Pooecetes gramineus*	11	3
Golden-crowned Kinglet	*Regulus satrapa*	25	4
Western Meadowlark	*Sturnella neglecta*	68	8
European Starling	*Sturnus vulgaris*	66	13
Barn Owl	*Tyto alba*	33	4
Mourning Dove	*Zenaida macroura*	13	6
White-crowned Sparrow	*Zonotrichia leucophrys*	13	3

Raptors

Raptors are the species of most concern, owing to the early observations of golden eagle, red-tailed hawk and American kestrel in the areas of Altamont Pass and Tehachapi wind farms, USA (Erickson *et al.,* 2001). Factors that contribute to the high mortality rates of raptors in California are unusual density, topography, and probably also the outdated turbine technology (Kingsley and Whittam, 2003). Raptors' fatalities are considered an important issue owing to their small population and protected status. Except for Altamont Pass, the number of fatalities is relatively small. Other species harmed by wind turbines are *Buteo regalis*, *Circus cyaneus*, *Falco mexicanus*, *Asio otus*, *Asio flammeus*, *Elanus leucurus*, *Buteo swainsoni*, *Cathartes aura, Tyto alba, Athene cunicularia*, *Otus flammeolus, Bubo virginianus* (Erickson *et al.,* 2001).

The endangerment of species depends on their presence and population size in the area of wind power projects. However, none of the studies has actually established the impact on population in the areas of wind power projects. In wind farm areas*, Falco sparverius* is the most frequently noticed raptor species. Consequently, it is most prone to collisions (Altamont Pass/California, Tehachapi Pass/California, Stateline/Oregon, Foote Rim Creek/Wyoming, Buffalo Ridge/Minnesota). The number of owl fatalities varies from 0.0% to 15% of total bird mortality in different areas. Namely, they usually fly at the height of turbines or lower and are thus prone to collisions (Kingsley and Whittam, 2005). There are very few fatalities among the raptors outside California – only 2.7% of all bird fatalities in the USA (Erickson *et al.,* 2001) or 6 raptors (Kerlinger, 2000). A smaller number of fatalities is caused by more appropriate turbine placement (away from high density and unfavourable landforms). It seems that construction of tubular towers with a slower blade speed also improves the conditions.

Topography is an important factor, as it is evident from the comparison of Tehachapi Pass and San Gorgonio, both in the USA. Tehachapi Pass is located in the south-central California at an altitude of 1000-1600 metres. It includes several ridges, slopes and 500 turbines of different forms and sizes. San Gorgonio is located at an altitude of 180-850 metres. It includes 3750 turbines, also of different forms and sizes. The recorded mortality was significantly higher in the area of Tehachapi Pass (15 *Buteo jamaicensis,* 1 *Buteo regalis,* 11 *Falco sparverius* and 1 *Falco mexicannus*) than in the area of San Gorgonio (1 *Buteo jamaicensis*) (Anderson *et al.,* 2000).

It is essential for environmental reports to provide the size of raptors population and topographic features of the area. These two factors have to be considered to avoid hazardous areas in wind power projects.

Passerines and other birds

Sparrows that occasionally migrate are the most affected birds in the wind farm areas. They present more than 80% of the monitored fatalities (Erickson *et al.,* 2001). This mortality rate does not endanger the population of particular species. Namely, in the most common species (e.g. European starling, American robin, grassland lark) the mortality is low and the populations are numerous.

The number of bird fatalities significantly varies from one wind farm to another. There are no or hardly any correlations between the number of birds in the area and the number of collision fatalities. In Buffalo Ridge, Minnesota, which is an important bird migration zone, the researchers estimated more than 3.5 million birds annually by using radar technology (Johnson *et al.,* 2002). Despite their numerosity, the number of collision fatalities was low. In the first two years of turbine operation, they reported 0.49 fatalities/turbine/year. Later, when the wind farm grew larger (from previous 73 to 354 turbines), a new estimation was made. The mortality was now 1,009 birds per year, or 2.85 fatalities/turbine/year (Johnson *et al.,* 2002). In spite the numerosity of passerines, there were no recorded fatalities elsewhere (Erickson *et al.,* 2001, Kerlinger, 2000). Although the largest number of collisions is in this bird group, the numbers still remain low in comparison to the total number of birds in the wind farm areas (Everaert, 2003). None of the studies has confirmed a negative impact on the population yet.

Pigeons are also considered sensitive to turbine collisions. *Columba livia* is an unprotected species which is a frequent collision victim. In the area of San Gorgonio wind farm this species presents 23.8% of all collisions and in the area of Altamont Pass 15% (Erickson *et al.,* 2001). Game birds are rarely exposed to collisions, since they generally fly at altitudes that are below the rotor height.

Waterbirds (gulls, herons, pelicans, terns, cormorants)

The mortality of these birds is low. The highest mortality rates occur in the area with a lot of water surfaces in the vicinity of turbines (California, Minnesota, Buffalo Ridge). Seagulls are supposed to be especially sensitive to collisions because they frequently fly at rotor height (Airola, 1987). However, the reported number of collisions is quite low, except for 3 locations in Belgium, mostly of *Larus argentatus, L. fuscus* and *L. ridibundus* (Everaert, 2003).

Waterfowl (coots, ducks, geese, swans)

The impacts on these species have been monitored in many wind farm areas, especially in Europe. Their interaction has been studied in fresh and seawater systems, in the vicinity of staging areas and along the migration corridors. Generally speaking, these species tend to avoid the turbines. Geese and swans rarely suffer fatalities due to collisions. In Blyth Harbour, Great Britain, they reported about eider fatalities. However, the number of collisions decreased in two years. This decrease probably occurred because eiders learnt how to avoid the turbines. Though, compared to the total eider population, the number of fatalities was quite low (Percival, 2001).

Shorebirds (plovers, snipes, godwits)

This group was thoroughly studied in the coastal areas of Europe with large populations of these species. Numerous *Calidris maritime* populations spend winters in the area of Blyth Harbour (Lowther, 2000). However, there are no records of collision fatalities. Two dead birds (*Haematopus ostralegus, Gallinago gallinago*) were found in an estuary area in Netherlands (Musters *et al.,* 1996). In Buffalo Ridge, only one fatality (*Charadrius vociferus*) was recorded in six years of study (Johnson *et al.,* 2002).

Breeding birds

The collision rate is usually lower for non-territorial species than for territorial ones. The reason is probably in their recognition of obstacles and the ability to avoid them. Habitat loss and disturbance and the loss of nests influence the breeding birds significantly.

The highest number of turbine fatalities was recorded for a raptor species *Buteo jamaicensis* (most of them in Altamont Pass), followed by a seagull species *Larus argentatus* (most of them in Belgian wind farms), a passerine *Eremophila alpestris* (Stateline and Foote Creek) and a pigeon species *Columbia livia* (Altamont Pass). These fatalities occurred in larger wind farms. However, the IUCN Red List of Threatened Species (2007) registers only one bird species as near threatened – red kite (*Milvus milvus* - 44 fatalities). All other bird species mentioned above are registered as least concern species.

Most wind farms do not face collision problems. The number of collisions is higher in the areas with raptor populations, high frequency of flying and high density of wind turbines. No study has confirmed a significant impact on the population. A lower number of victims in modern turbines is probably the result of better turbine placement, away from high bird density and away from unfavourable topography. The impact of modern turbine design is also worth mentioning. Then again, there are many studies about numerous bird fatalities at various tall structures (Evans Ogden, 1996; Orloff and Flannery, 1996; Winkelman, 1994).

The collected data provides an average of 2 bird fatalities per turbine annually, regardless of species. In 2006, the total wind plant capacity was about 55,000 MW, which means 2 MW per turbine for 27,500 turbines that operated in that year. To sum up, the total number of fatalities is approximately 55,000, which is relatively low in comparison to the estimated number of annual collisions with other tall structures.

American studies usually focus on the number of bird fatalities in particular wind farms, while the European studies pay more attention to the particular bird species and provide impact assessments for them.

Disturbance effect

It is generally known that birds avoid turbines. Problems mostly occur with migrating and breeding birds, or in the feeding areas. The disturbance effect reaches as far as 75-800 metres from the turbines (Strickland and Erickson, 2003). Migrating birds seem to be more sensitive than breeding ones which is obviously due to the process of adjustment. Most small birds can easily avoid the turbines while this is harder for larger birds that also demand more distance to the wind farm. When they compared fatalities to their reactions to turbines, they found sensitive species less exposed to risk than others. Raptors, seagulls and starlings often become fatalities, while shorebirds and geese do not. As an exception, crows showed no fear and were also rarely recorded as fatalities. A further research would be required to assess the reaction of particular species.

Most authors emphasize birds' distance of at least 100 m for following species: Montagu's harrier (Bergen, 2002), common buzzard, kestrel and red kite (Brauneis, 1999). Avoidance of turbines is typical for the following grassland species: common quail, corn crake (Bergen, 2002), lapwing, oystercatcher and ringed plover (Pedersen and Poulsen, 1991). Migrating birds avoid more frequently, especially geese (Schreiber, 2002; Pedersen and Poulsen, 1991), common cranes (Brauneis, 1999, 2000), lapwings (Schreiber, 2002; Bergen, 2002; Brehme, 1999; Clemens and Lammen, 1995; Winkelman, 1992; Pedersen and Poulsen 1991), and golden plovers (Schreiber, 2002; Brehme, 1999; Clemens and Lammen, 1995; Pedersen and Poulsen, 1991). Yet some authors recorded no avoidance effects for the above mentioned species. Among waterbirds, geese are an exception (Kruckenberg and Jaene, 1999), but not in spring resting location in Gotland where geese feed right next to the turbines, within less than 25 m distance (Percival, 1998; cit. Traxler *et al.,* 2004).

Monitorings and bat mortality rate in wind farms

The first report on bat mortality due to collisions goes back to 1930, when Sounders recorded 5 fatalities next to an illuminated house in Ontario, Canada. 5 red bats were recorded as fatalities next to a TV tower in Kansas (Van Gelder, 1956). Since 1960, bats have also been considered as wind turbine fatalities (Hall and Richards, 1972). Bat fatalities have recently been studied mostly in the USA. In some wind farms there are hardly any or no bat fatalities, and in others there are many victims among the bats. In comparison to birds, there is much less information available on bat mortality. The available information is also quite dispersed.

The impact of wind turbines on bats has gained more attention after studying the high bat mortality at Mountaineer Wind Energy Centre in West Virginia (Johnson and Strickland, 2004; Kerns and Kerlinger, 2004). From 4/4 to

11/11/2003 there were 475 fatalities (7 bat species). 31 % of them were *Myotis lucifugus* and *Pipistrellus subflavus.*

2,092 fatalities per turbine were estimated in that period and the mortality rate was 47.53 per turbine. Most fatalities (92.5%) were found between 18/8/2003 and 30/9/2003 (Kerns and Kerlinger, 2004). 3 turbines in Buffalo Mountain wind farm were monitored for 3 years. They recorded 119 bat fatalities (Johnson and Strickland, 2004). 61 % belonged to a bat species called *Lasiurus borealis* (Kerns and Kerlinger, 2004). Bat migrants seem to be more endangered than the resident, feeding or breeding ones (Erickson *et al.,* 2004; Johnson and Strickland, 2004).

Wind farms differ according to the number of turbines, from 1 to more than 5400. Most mortality calculations include the efficiency of fatality searching and the removal of carcasses, but some do not. A total of 23 studies report on the mortality rate of all bat species. Bat annual mortality rates range from 0.0 (Obersdorf/Austria, Alaiz/Spain, El Perdon/Spain, Guerinda/Spain) up to 47.5 fatalities/turbine/year in Mountaineer, USA. Out of 20 monitorings, most researches took a year (80% of the researches with defined duration).

In Germany, there have been 285 bat fatalities recorded since 1998. The fatalities occurred mostly among the following species: *Nyctalus noctula* (132), *Pipistrellus nathusii* (51), *Vespertilio murinus* (10) and *Nyctalus leisleri* (14). The mortality rate in Brandenburg was 0.23 fatalities/turbine/year (Dürr, 2003). Compared to birds, there was a stronger relation between mortality rate and turbine size, but it was not statistically important. In three Austrian wind farms, the total bat mortality was 14 bats or 2.8 fatalities/turbine/year. Prallenkirchen wind farm reported most fatalities. The rate in Obersdorf was 0.0, in Prallenkirchen 8.00 and in Steinberg 5.33. The differences arise from the size of wind farms and from the success in finding the fatalities (Traxler *et al.,* 2004). Bat mortality was also recorded in Scandinavia. In Sweden, there were 17 fatalities of 6 species at 160 turbines (Ahlen, 2002). The average mortality rate in the USA was 3.4 bats/turbine/year or 4.6 per MW per year. The highest mortality was recorded in Mountaineer/West Virginia. In other regions the mortality is low. According to the existing data, there were 1628 bat fatalities, 90% of them from mid July to mid September and 50% in August (Johnson and Strickland, 2004). *Lasiurus cinereus* and *L. borealis* are most frequent wind turbine fatalities in mid west and east of the USA. *Lasiurus cinereus* and *Lasionycteris noctivagans* are also two most commonly noticed bat species in 11 states.

The impact on population is hard to determine because there is no accurate data on the number of fatalities from individual species. For most bat populations, the increase in number is slower than for other small mammals. High mortality can cause a population decline (Keeley *et al.,* 2001). The reasons for collisions have not been fully studied yet (Osborn *et al.,* 1996). Most collisions happen during migration and are usually connected to bad weather, which forces the birds to fly lower and can cause disorientation of bats. At a communication tower in Florida, the high mortality of birds was accompanied by the high mortality of bats (Crawford and Baker, 1981).

Table 2. The number of fatalities among the bat species in different wind farms and countries

Bat species	Latin name	USA Foote Creek	USA Buffalo Ridge	USA Buffalo Mountain	USA Wisconsin	USA Stateline	USA Mountaineer	USA Nine Canyon	USA Vansycle	USA Klondike	USA Altamont	USA San Gorgonio	USA Tehac hapi	GERMANY	AUSTRIA	AUSTRALI A	TOTAL
	Chalinolobus gouldii															9	9
Big brown bat	*Eptesicus fuscus*	2	15	2	1	2	2										24
Silver haired bat	*Lasionycteris noctivagans*	5	20	1	13	73	28	15	3	1							159
Eastern red bat	*Lasiurus borealis*		73	48	27		200										348
Hoary bat	*Lasiurus cinereus*	119	273	10	25	71	88	12	5	3	1						607
Little brown bat	*Myotis lucifugus*	6	8			1	60		1								76
Leisler's bat	*Nyctalus leisleri*													14			14
Noctule bat	*Nyctalus noctula*													132	11		143
Nathusius pipistrelle bat	*Pipistrellus nathusii*													51	2		53
Eastern pipistrelle	*Pipistrellus subflavus*		7	11			87										105

Cont. Table 2.

Bat species	Latin name	USA Foote Creek	USA Buffalo Ridge	USA Buffalo Mountain	USA Wisconsin	USA Stateline	USA Mountaineer	USA Nine Canyon	USA Vansycle	USA Klondike	USA Altamont	USA San Gorgonio	USA Tehac hapi	GERMANY	AUSTRIA	AUSTRALI A	TOTAL
Brown long-eared bat	*Plecotus auritus*						6										6
Grey long-eared bat	*Plecotus austriacus*														1		1
Parti-coloured bat	*Vespertilio murinus*													10			10
Undetermined		3	24		6	3	4		1	2		1	1			2	47
Sum		135	420	72	72	150	475	27	10	6	1	1	1	207	14	11	1602

Sources: Austria (Traxler, 2004); Australia (Hydro Tasmania, 2004); Tehachapi Pass, San Gorgonio, USA (Anderson *et al.,* 2000); Foote Creek, USA (Young *et al.,* 2003); Nine Canyon, USA (Erickson *et al.,* 2003b); Vansycle, USA (Erickson *et al.,* 2000); Buffalo Ridge, USA (Johnson *et al.,* 2003b); Mountaineer, USA (Johnson *et al.,* 2004); Klondike, USA (Johnson *et al.,* 2003); Stateline, USA (Stateline, 2004); Wisconsin, USA (Johnson *et al.,* 2003b)

It is unlikely that most fatalities occur among territorial species. If this was the fact, most collisions would occur while feeding. However, there is not a lot of food close to the turbines. Most species find food next to water and trees (Carter *et al.,* 1999; Everette *et al.,* 2001). Bats do not usually feed at around 25 m above the ground and this is also the lowest altitude of wind turbine rotation (Fenton and Bell, 1979). To mitigate the mortality of bat species, new wind turbines should not be located in wintering, feeding and nesting areas and along migration corridors.

The appropriate estimation of biological resources can lower costs and postpone the projects. It can also minimize the disappointment of environmental organisations and even help with meeting all the necessary requirements. Despite all the studies, a considerate location of wind farms is still the best way to minimize the negative impacts.

Critical areas should be avoided when planning wind farms (areas with highly sensitive species, important migration areas, resting, feeding and nesting areas). The surrounding can also cause collisions, especially if there are better chances for prey. The constructors should avoid additional structures that present a threat to birds and bats (roads, fences). The carcass is very attractive to birds and should be removed regularly. There is enough information to make a general estimation of development that could help to prevent problems. Raptors are evidently most exposed to collisions, also because of the bad experiences from Altamont Pass. However, the data also shows that raptors usually avoid turbines. Thus, the documented mortality is very low. The awareness of factors that contributed to the mortality in California (topography, high density of raptors, outdated technology) helped to minimize the mortality in other wind farms. Passerines were most common collision fatalities, but the impacts on the population have not been established yet.

Generally speaking, wind energy has little influence on bird species. However, there are some exceptions where mortality was quite high. High mortality can be perceived very subjectively, but when comparing to the average calculation of mortality rates we can set some limits (above 2 fatalities/turbine/year for birds, above 0.34 for raptors and above 3.6 for bats).

Table 3. SWOT analysis of wind farms including the impact on animal species

STRENGTHS	WEAKNESSES
• Clean and renewable energy source • No atmospheric emissions and therefore reduction of greenhouse gases in the atmosphere • No study records the important influence on the population of individual animal species • Low risk for birds when compared to other human activities	• Warning lights on turbines are mandatory in some areas • The largest mortality is recorded for passerines species *Eremophila alpestris* and *Columbia livia*, with raptor species *Buteo jamaicensis*, with waterbirds for gull *Larus argentatus* • The largest mortality is recorded for bat species *Lasiurus cinereus*, *Lasiurus borealis*, *Lasionycteris nostivagans* • One recorded fatality is endangered species red kite (*Milvus milvus*) • Longer monitoring of birds and bats before the construction
OPPORTUNITIES	THREATS
• Use of renewable energy sources in the areas assessed as appropriate • Reduction of greenhouse gases • Location of wind farms in the area of increased bird and bat activity only with mitigating measures (taboo zones, appropriate distance between turbines and nesting places)	• Unplanned activities affecting the environment • No advance monitoring for threatened animal species • Location in critical areas with a large number of very sensitive species • Vegetation around the turbines is very attractive for small mammals • Proximity of nesting places of endangered species • Areas of important migration paths • Wetlands • Mountain ridges • Areas with a large number of foggy days, cloudiness and low visibility at a larger number of raptors

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REFERENCES

1. *Airola D,* 1987, Bird abundance and movements at the Potrero Hills Wind Turbine Site, Solano County, California, prepared for the Solano County Department of Environmental Management, Fairfield, California.
2. *Ahlen I,* 2002, Fladdermoss och faglar dodade av vindkraftverk, (Bats and Birds killed by Wind Power Turbines), *Founa och flora*, 97, 14-21.

3. *Anderson R,* 2000, Avian monitoring and Risk Assessment at Tehachapi Pass and San Gorgonio Pass Wind Resource Area, California: Phase I Preliminary Results, In: In: *Proc Nat Avian – Wind Power Plan Meet III*, San Diego, Kalifornija 1998, Environmental Research Associates, Ontario, Kanada, http://www.nationalwind.org/publications/wildlife/avian98/default.htm (13.1.2006)
4. *Bach L,* 2003, Effekte von Windenergieanlagen auf Fledermäusse, In: Kommen die Vögel und Fledermäusse unter die (Wind)räder? Dresden, 17-18.11.2003.
5. *Barclay RMR,* 1984, Observations on the migration , ecology and behaviour of bats at Delta Marsh, Manitoba, *Canadian Field- Naturalist*, 98, 331-6.
6. *Bergen F,* 2002, Windkraftanlagen und Frühjahrsdurchzug des Kiebitz (*Vanellus vanellus*): eine Vorher/Nachher Studie an einem traditionellen Restplatz in Nordrhein Westfalen, www.tu-berlin.de/člbp/schwarzesbrett/tagungsband.htm (12.1.2006)
7. *Brauneis W,* 1999, Der Einfluss von Windkraftanlagen auf die Avifauna am Beispiel der "Solzer Höhe" bei Bebra Solz im Landkreis Hersfeld-Rotenburg-Untersuchung im Auftrag des Bundes für Umwelt und Naturschutz Landesverband Hessen e. V. – *Ortsverband Alheim- Rotenburg-Bebra*, 1-91.
8. *Brauneis W,* 2000, Der Einfluss von Windkraftanlagen auf die Avifauna, dargestellt insb, Am Beispiel des Kranich Grus grus, *Ornith Mitteil*, 52, 410-5.
9. *Brehme S,* 1999, Ornithologische Beobachtungen in unmittelbarer Nähe von Windkraftanlagen, Naturschutzarbeit in Macklenburg Vorpommern, 42, 2, 55-60.
10. *Carter TD, Menzel MA, Chapman BR, Miller KV, Lee JR,* 1999, A new method to study bat activity patterns, *Wildl Soc Bull*, 27, 598-02.
11. *Clemens T, Lammen C,* 1995, Windkraftanlagen und Rastplätze von Küstenvögeln- ein Nutzungskonflikt, *Seevögel*, 16, 34-8.
12. *Crawford RL, Baker WW,* 1981, Bats killed at a north Florida televison tower: a 25-year record, *J Mamm,* 62, 651-2.
13. *Dürr T*, 2003, Windenergieanlagen und Fledermausschutz in Brandenburg – Erfahrungen aus Brandenburg mit Einblick in die Bundesweite Fundkartei von Windkraftopfern, In: Kommen die Vögel und Fledermäuse unter die (Wind) räder? Dresden, 17-18.11.2003.
14. *Erickson WP, Strickland MD, Johnson GD, Kronner K,* 2000, Avian and bat mortality associated with the Vansycle Wind Project, Umatilla County, Oregon: 1999, study year, Technical Report prepared by WEST, Inc for Umatilla County Department of Resource Services and Development, Pendleton, Oregon, 21.
15. *Erickson WP, Johnson GD, Strickland MD, Young DP, Sernka KJ, Good RE,* 2001, Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States, National Wind Coordinating Committee Resource Document, 62, www.nationalwind.org/pubs/avian_collisions.pdf (17.7.2006)
16. *Erickson WP, Jeffrey J, Konner K, Bay K,* 2003, Stateline Wind Power Project Wildlife monitoring Annual Report, Result from the Period July 2001-December 2002, Technical Report submitted to FPL Energy, the Oregon Office of Energy and the Stateline Technical Advisory Committee.
17. *Erickson WP, Kronner K, Gritski B*, 2003b, Nine Canyon Wind Power Project avian and bat monitoring report, Prepaired for Nine Canyon Tehnical Advisory Committee Energy Northwest, http://www-west-inc.com/wind_reports.php (17.7.2006)
18. *Erickson WP, Johnson GD, Young DP,* 2004, Summary of anthropogenic causes of bird mortality, In: Proceedings of the 2002 International Partner's in Flight Conference, Monterrey, California.
19. *Evans Ogden LJ,* 1996, The hazards of lighted structures and windows to migrating birds, Report from the World Wildlife Fund Canada, Toronto, Canada (unfinished report).
20. *Everaert J,* 2003, Wind Turbines and Birds in Flanders : Preliminary Study Results and Recommendations, *Natuur Oriolus*, 69, 4, 145-55.
21. *Everette AL, O'Shea TJ, Ellison LE, Stone LA, McCance JL,* 2001, Bat use of high plains urban wildlife refuge, *Wildl Soc Bull*, 29, 967-73.
22. *Fenton MB, Bell GP,* 1979, Echolocation and feeding behavior in four species of Myotis, *Can J Zool*, 57, 1271-7.

23. *Hall LS, Richards GC,* 1972, Notes on *Tadarida australis* (Chiroptera:molossidae), *Austral Mamm*, 1, 46.
24. Hydro Tasmania, 2004, Bird and bat monitoring, http://www.hydro.com.au/documents/Our%20Environment/BirdAndBatMonitoringAtTheWoolnorthWindfarm.pdf (22.12.2006)
25. *Johnson GD, Erickson WP, Strickland MD, Shepherd MF, Shepherd DA, Sarappo SA,* 2002, Collision mortality of local and migrant birds at a large scale wind power development on Buffalo Ridge, Minnesota, *Wildl Soc Bull*, 30, 879-87.
26. *Johnson GD, Erickson WP, White J, McKinney R,* 2003, Avian and Bat mortality during the first year of operation at the Klondike Phase I Wind Project, Sherman County, Oregon, Draft prepared for : Northwest Wind Power, http://www.west-inc.com/reports/klondike_final_mortality.pdf (12.2.2007)
27. *Johnson GD, Erickson WP, Strickland MD, Shepherd MF, Shepherd DA,* 2003b, Avian monitoring studies at the Buffalo Ridge Minnesota Wind Resource Area: Results of a 4 –Year Study, Western Ecosystems Technology, Inc., 273, http://www.west-inc.com/wind_reports.php (12.2.2007)
28. *Johnson GD, Strickland MD,* 2004, An Assessment of Potencial Collision Mortality of Migrating Indiana Bats (*Myotis sodalis*) and Virginia Big-eared Bats (*Corynorhinus townsendii virginianus*) Traversing Between Caves: Supplement to Biological Assessment for the Federally Endagered Indiana Bat (*Myotis sodalis*) and Virginia Big-eared Bats (*Corynorhinus townsendii virginianus*), Western Ecosystems Technology, Inc, 24, http://www.west-inc.com/reports/finalbatsupplement.pdf (22.12.2006)
29. *Keeley B, Ugoretz S, Strickland D,* 2001, Bat ecology and wind turbine considerations, In: *Proc Nat, Avian – Wind Power Plan Meet*, National Wind Coordinating Committee, Washington, DC 4, 135-46.
30. *Kerlinger P*, 2000, Avian mortality at communication towers: a review of recent literature, research, and methodology, Unpublished report prepared for the US Fish and Wildlife Service, Office of Migratory Bird Management, http://migratorybirds.fws.gov/issues/towers/review.pdf (22.12.2006)
31. *Kerns J, Kerlinger P,* 2004, A Study of Bird and Bat Collision Fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003, Technical Report prepared for FPL Energy and Mountaineer Wind Energy Center Technical Review Committee, Curry and Kerlinger, LLC, 39.
32. *Klem D Jr,* 1990, Collisions between birds and windows: mortality and prevention, *J Field Ornithol,* 61, 1, 120-8.
33. *Kingsley A,Whittam B,* 2003, Wind turbines and birds, A Guidance Document for Environmental Assessment, Canadian Wildlife Service, 87, http://www.wolfeislandwind.com/planning_docs/BSC_Bird_Report(May2004).pdf (13.5.2006)
34. *Kingsley A,Whittam B,* 2005, Wind turbines and birds, A Background Review for Environmental Assessment, Canadian Wildlife Service, 81.
35. *Koops FBJ,* 1993, Collisions victims of high-tension lines in the Netherlands and effects of marking, NV KEMA, Arnhem, The Nedherlands, 6.
36. *Kruckenberg H, Jaene J,* 1999, Zum Einfluss eines Windparks auf die Vertailung weidender Bläâgänse im Rheiderland, *Natur und Landschaft*, 74, 420-7.
37. *Larsen LK, Madsena J,* 2000, Effects of wind turbines and other physical elements on field utilization by pink footed geese: a landscape perspective, *Landscape Ecol*, 15, 755-64.
38. *Lowther S,* 2000, The European Perspective: Some Lessons from Case Studies, In: *Proc Nat Avian – Wind Power Plan Meet III*, San Diego, Kalifornija 1998, Environmental Research Associates, Ontario, Kanada, http://ww.nationalwind.org/pubs/avian98 (13.5.2006)
39. *Orloff S, Flannery A,* 1996, A continued examination of avian mortality in the Altamont Pass Wind Resource Area, P700-96-004CN, *Rep from Ibis Environ Serv And BioSystems Analysis Inc,* Santa Cruz, CA, for Calif Energy Commis, Sacramento, CA, 55.
40. *Osborn RG, Higgins KF, Usgaard RE, Dieter CD,* 1996, Bat collisions with wind turbines in Southwest Minnesota, *Bat Res News*, 37, 105-8.

41. *Pedersen MB, Poulson E,* 1991, Impact of a 90 m/2 MW wind turbine on birds, Avian responses to the implementation of the Tjaereborg Wind Turbine at the Danish Wadden Sea, Danske Vildtundersogelser 47, Kalo.
42. *Percival SM,* 2001, Assessment of the effect of offshore Wind farms on Birds, ETSU Report W/13/00565/REP.
43. *Schreiber M,* 1993, Zum Einfluss von Störungen auf die Rastplatzwahlvon Watvögeln, *Inform d Natursch Niedersachs*, 13(5), 161-9.
44. *Schreiber M,* 2002, Einfluss von Windenergieanlagen auf Rastvögel und Konsequenzen für EU Vogelschutzgebiete, Tagungsband zur Fachtagung Windenergie und Vögel - Ausmass und Bewältigung eines Konfliktes, 29.-30.11.01, Berlin, www.tu-berlin.de/člbp/schwarzesbrett/tagungsband.htm (13.5.2006)
45. Stateline Wind Project Wildlife Monitoring Final Report, 2004, July 2001- December 2003, Western Ecosystems Technology, Inc Oregon, 105, http://www.west-inc.com/wind_reports.php (13.5.2006)
46. *Strickland D, Erickson W,* 2003, Overview of Non-collision Related Impacts from Wind Projects, Western Ecosystems Technology, Wyoming, 13.
47. *Thelander CG, Rugge L,* 2000, Avian risk behavior and fatalities at the Altamont Wind Resource Area - March 1998 to February 1999, Prepared by BioResource Consultants for the National Renewable Energy Laboratory, Golden, CO, 23.
48. *Traxler A, Wegleitner S, Jaklitsch H,* 2004, Vogelschlag, Meideverhalten & Habitatnutzung an bestehenden Windkraftanlagen Prallenkirchen-Obersdorf-Steinberg/Prinzendorf, Ökoenergie, 103.
49. *Van Gelder RG,* 1956, Echo-location failure in migratory bats, *Trans Kans Acad Sci,* 59, 220-2.
50. *Winkelmann JE,* 1992, De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.)op vogels, 1: aanvaringsslachtoffers, RIN-rapport 92/2, DLO Instituut voor Bos- en Natuuronderzoek, Arnhem, Nederlands, 71p + Appendices. (Dutch with Engl Summ), Winkelman JE 1995, Bird/wind turbine investigations in Europe, In: *Proc Nat Avian – Wind Power Plan Meet,* Denver, CO, July 1994, 110-40.
51. *Winkelmann JE,* 1994, Bird/wind turbine investigations in Europe, In: *Proc Nat Avian – Wind Power Plan Meet,* Denver, CO, July 1994, DE95-004090. RESOLVE Inc, Washington, DC, and LGL Ltd, King City, Ont, 43-7, www.nationalwind.org/pubs/avian94/default.htm (13.5.2006)
52. *Young DP, Erickson WP, Strickland MD, Good RE, Semka KJ,* 2003, Comparison of Avian Responses to UV Light Reflective Painton Wind Turbines, Subcontract Report: July 1999-December 2000, National Renewable Energy Laboratory, 67, http://www.osti.gov/bridge (15.5.2006)

UTICAJ VETRENJAČA ZA PROIZVODNJU ELEKTRIČNE ENERGIJE NA RAZLIČITE ŽIVOTINJSKE VRSTE

STERŽE JANA i POGAČNIK M

SADRŽAJ

Vetrenjače za proizvodnju električne energije se grade i postavljaju u različitim delovima sveta bez obzira na prisustvo zaštićenih životinjskih vrsta. U 55%, do sada objavljenih studija, mortalitet ptica se kretao u opsegu od 0-2 uginuća/turbini godišnje. U 79,4 % slučajeva mortalitet grabljivica je iznosio 0-0,1 uginuća/turbini godišnje. Najveći broj uginuća je zabeležen kod vrste *Buteo ja-*

maicensis a zatim kod vrsta *Larus argentatus*, *Eremophila alpestris* i *Columba livia*. Jedina vrsta čija su uginuća zabeležena a nalzi se na listi ugroženih vrsta je bila *Milvus milvus*. U novije vreme, u Evropi se sve više pažnje posvečuje ovom problemu i procenjuje se da su najugroženije vrste ptica grabljivice, selice, plovuše i koke. Ugnuća su zabeležena i kod slepih miševa i to vrsta *Laisurus cinereus*, *Laisurus borealis*, *Lasionycteris noctivagans* i *Nyctalus noctula*.